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A 33-GVA INTERRUPTER TEST FACILITY*

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ABSTRACT

The use of commercial ac circuit breakers for dc switching operations requires that they be evaluated to determine their dc limitations. Two 2.4-GVA facilities have been constructed and used for this purpose at LASL during the last several years. In response to the increased demands on switching technology, a 33-GVA facility has been constructed. Novel features incorporated into this facility include (1) separate capacitive and cryogenic inductive energy storage systems, (2) fiber-optic controls and optically-coupled data links, and (3) digital data acquisition systems. Facility details and planned tests on an experimental rod-array vacuum intertupter are presented.

INTRODUCTION

Since 1975 the Los Alamos Scientific Laboratory (LASL) has been conducting experiments with commerical ac circuit breakers to determine their direct-current ratings for potential application in various fusion devices.[1,2] Particular attention has been paid to the vacuum intertupter due to its low cost, mechanical simplicity, and its ruggedness. Because of these advantages, fusion experiments such as Alcator, TFTR, and Doublet III utilize vacuum intertupters in their switching systems. Interrupters used in both TFTR and Doublet III require current interruption in the 25 kA to 30 kA range with associated recovery voltages of 20 kV to 25 kV. Preliminary designs for larger devices such as ETF indicate that a trend towards higher currents may be economical if low-cost switching systems exist that can satisfy the interruption requirements. For this reason a facility has been constructed at LASL which is capable of evaluating circuit breakers for application in the next generation of fusion experiments.

PRESENT TEST FACILITIES

In addition to the facility discussed in this paper, two smaller facilities are presently used for intertupter testing.[3] These facilities are essentially identical and are rated at 2.4 GVA each. They can be connected in parallel for high-current tests, or operated independently for tests up to 40 kA. The new 33-GVA facility will be capable of tests as high as 280 kA. A summary of the facilities ratings is given in Table I.

TABLE I.
SUMMARY OF FACILITIES RATINGS

	FACILITY		
	A	B	C
Peak power	2.4	2.4	33.6
Stored energy (kJ)	450	450	2250
Rated current (kA)	40	40	280
Max. recovery voltage (kV)	60	60	120
Completion date	1975	1977	1979

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FACILITY DETAILS

Energy Storage Systems. The facility is unique in that it has two independent primary energy storage sytems. The first is a capacitive system, the second is a cryogenic inductor system.

The capacitive system consists of seven modules, each containing 270 kJ of 20 kV capacitors, a four-segment 60-kA inductor, two independent shorting systems, fuses, and associated hardware. A schematic and photograph of a storage module are shown in Figs. 1 and 2.

Current is initiated in inductor L, and the load by discharging capacitor C through ignitron Ig_1. At peak current, self-firing ignitrons Ig_2 and Ig_3 crowbar the capacitor thereby preventing oscillation. The current trapped in the inductor now serves as the load current for the switch under test.

Figure 3 is a schematic showing a typical test circuit which uses these storage modules. The load current supplied by inductors L circulates through the test breaker, B_T, and its saturable reactor, L_{SR}. The breaker is then opened. A counterpulse from capacitors C_2 brings the current in the breaker to zero where it interrupts. The residual energy in L is transferred to C_2, generating a recovery voltage across the test breaker. Figure 4 is a photograph of the seven storage modules during construction.

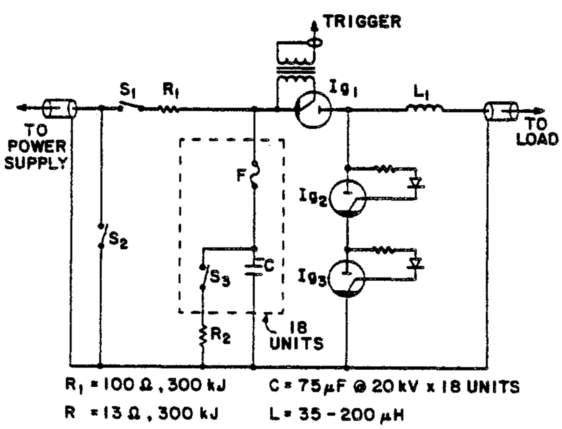

Fig. 1. Capacitive storage module schematic.

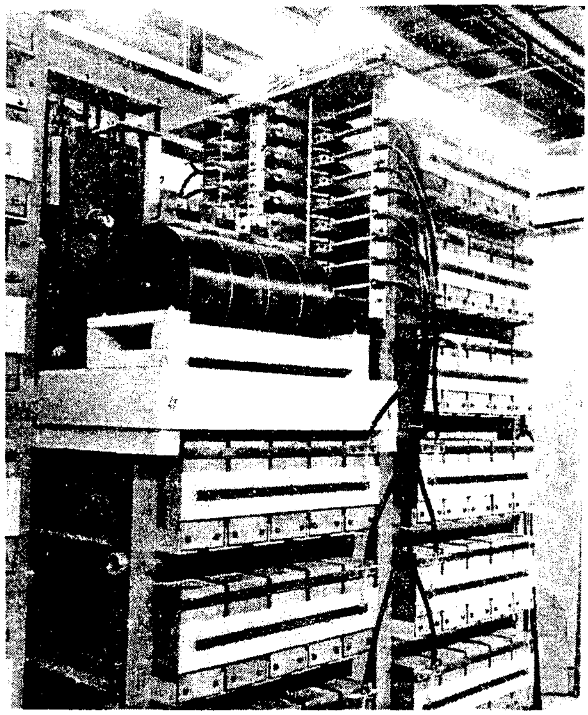

Fig. 2. Capacitive storage module photograph.

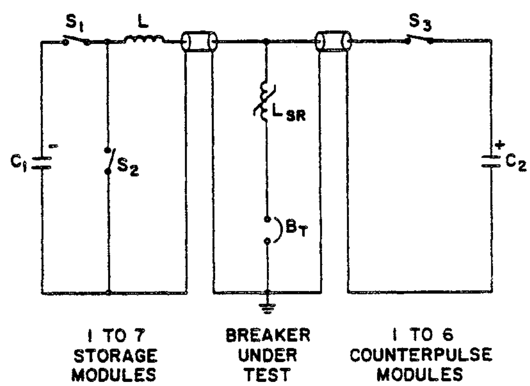

Fig. 3. Typical test circuit which uses storage modules.

The second energy storage system consists of six cryogenic inductors, which operate in a liquid N_2 bath at 80 K. These are charged externally by a 40-kA 12-V power supply. A test circuit which uses this scheme is shown in Fig. 5.

This test circuit is specifically designed to simulate the higher I^2t duty seen by an intertupter in the poloidal field coil system of a fusion device. In this circuit, current in cryo-inductor L and test breaker B_T is ramped up

Fig. 4. Capactive storage modules during construction.

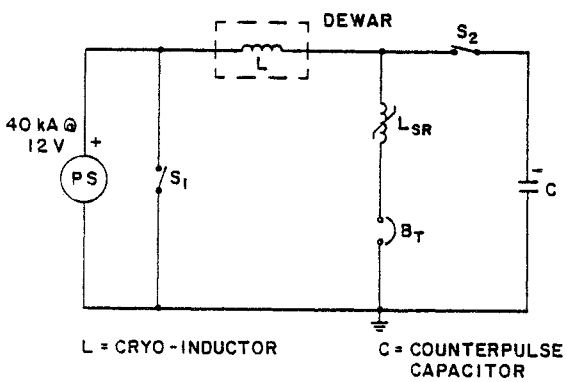

Fig. 5. Test circuit with cryogenic inductors.

by the dc power supply. At full current the power supply is turned off and switch S_1 closed. The test breaker opens, current is commutated, and the residual energy in L is transferred to C as in the previous scheme using capacitive storage. The total energy in this sytem is small compared to the capacitive system and will only be used for specialized tests.

Counterpulse System. The counterpulse system used with either storage system consists of six modules, each containing 300 µF of 20-kV capacitors. Each module has an independent shorting system and start ignitron. A schematic and photograph are shown in Figs. 6 and 7.

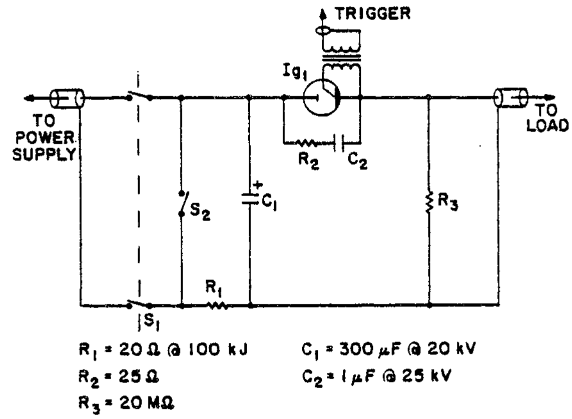

Fig. 6. Counterpulse module, schematic.

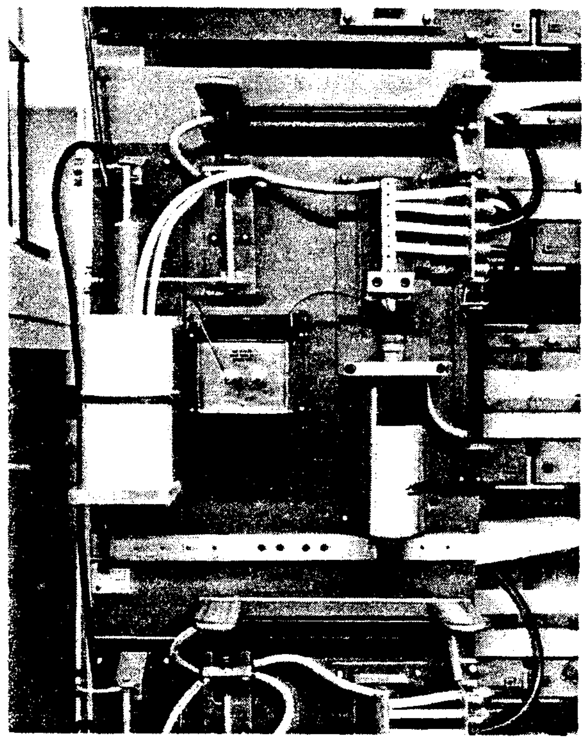

Fig. 7. Counterpulse module photograph.

These six modules can be connected in a series, a series-parallel, or a parallel arrangement depending on the capacitance and recovery voltage requirements for a particular set of tests. S_1 represents a DPST charging switch with 150-kV isolation between all contacts. This switch allows the counterpulse bank to be operated as a Marx generator where the modules are charged in parallel with a 20-kV power supply and then discharged in series at voltages up to 120 kV. Also, provisions have been made on each counterpulse modules for the connection of up to 300 μF of additional capacitance. This will be necessary in certain experiments, such as early counterpulsing, which require an unusually large counterpulse bank. The six counterpulse modules are pictured in Fig. 8.

Control System. The control system for the 33-GVA facility is a hybrid electrical-optical-pneumatic system with emphasis on the optical segment. Slow commands, such as shorting switches, isolation switches, and power supply signals, are transmitted electrically from the main control station to a midstation located just inside the facility doors. Here they are converted to optical signals which branch out to the various modules. At the modules these optical signals then operate electrical and pneumatic devices.

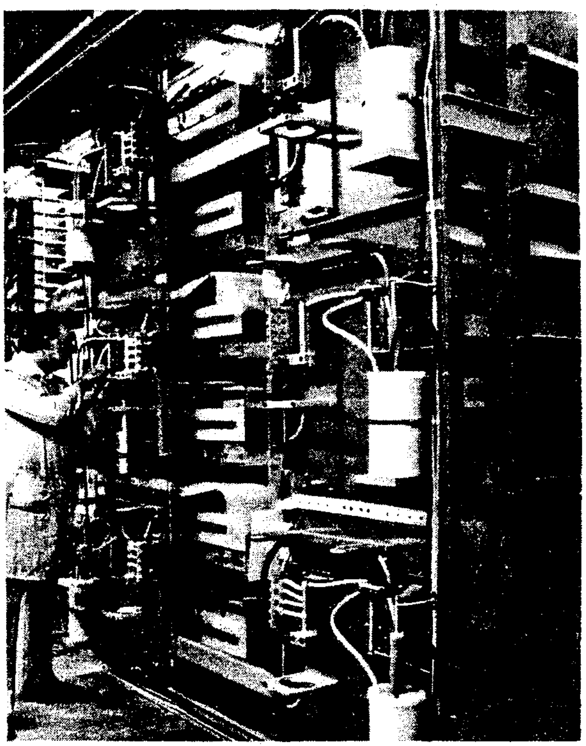

Fig. 8. Counterpulse modules under construction.

All fast commands for triggering ignitrons and breaker actuators originate at the control main station from a fifteen-channel digital delay generator. These triggers are immediately converted to optical pulses and transmitted via fiber-optic cables to high-voltage pulsers or actuator drivers located within the test facility. Power supply charging voltages and currents are converted to FM signals in the test facility and then transmitted optically to the main control station. Here they are demodulated and used to operate meters. This intense use of optical signals in high emf areas is of great benefit in the avoidance of ground loops and in the protection of personnel and sentitive control equipment.

Data Acquisition. Voltage and current waveforms are measured by voltage dividers and noninductive shunts in the test facility and converted to analog light signals. The analog light signals are transmitted on fiber-optic cables to the main control area where they are converted back to analog electrical signals. These signals are fed into digital oscilloscopes where they can be viewed. A small computer is also connected to the oscilloscopes and is capable of performing routine data analysis as well as storing waveforms on magnetic tape.

UPCOMING TESTS ON AN EXPERIMENTAL ROD-ARRAY VACUUM INTERRUPTER

The first breaker testing in the 33-GVA facility is planned for September, 1979. The intertupter to be tested is an experimental intertupter made by the General Electric Company. The device is referred to as a rod-array vacuum intertupter due to a novel internal geometry and shown promise of interrupting unusually large currents because of its ability to maintain a diffuse arc.[4]

Figure 9 is a general schematic of the circuit to be used in testing this intertupter. This circuit differs from the standard circuit of Fig. 3 in that each module now contains a saturable reactor and a vacuum intertupter in its primary discharge leg. After the test breaker,

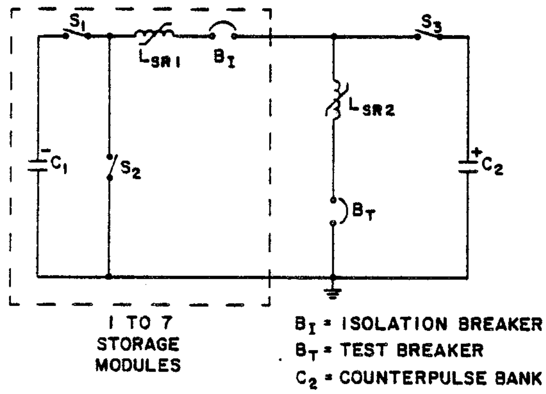

Fig. 9. Test circuit for experimental G.E. intertupter.

B_T, has interrupted the load current, the energy in the load coil and saturable reactor, L_{SR1}, is transferred to the counterpulse capacitor, C_2. At the instant of complete transfer, which is a current zero for B_I and L_{SR1}, B_I interrupts. This prevents further oscillation of L_{SRI} and C_2, thereby holding the recovery voltage on C_2 and B_T. A waveform for this type of test is shown in Fig. 10.

The recovery voltage will be maintain on the test breaker for 50 to 100 ms. This simulates intended use in tokamak systems and insures that the intertupter has fully recovered its dielectric strength.

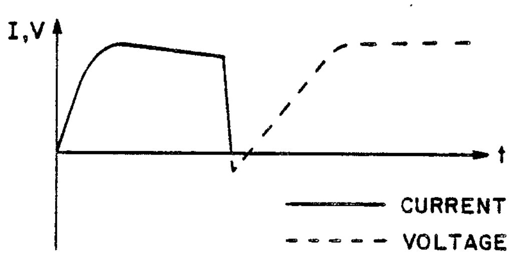

Fig. 10. Waveforms for experimental G.E. intertupter test.

CONCLUSIONS

A 33-GVA intertupter test facility has been constructed which is capable of testing intertupters for the next generatiion of experimental fusion devices. The facility is capable of producing currents of 280 kA with associated recovery voltages of 120 kV. Tests are planned on an experimental G.E. intertupter.

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